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# *Mobius Floe*: an Immersive Virtual Reality Game for Pain Distraction

Diane Gromala, Xin Tong, Chris Shaw, Ashfaq Amin, Servet Ulas, Gillian Ramsay

## ABSTRACT

*Immersive Virtual Reality (VR) has been shown to work as a non-pharmacological analgesic by inducing [sic] cognitive distraction in acute pain patients. Researchers have shown that VR games have the potential to distract patients cognitively and function as a type of pain management therapy. In this paper, we introduce the gameplay and design metaphors of Mobius Floe (MF), an immersive VR pain distraction game for acute and chronic pain patients. MF introduces an experimental approach with more engaging game interactivity to improve cognitive distraction for pain relief. In MF, we designed game mechanics with specific pain metaphors and therapeutic elements in immersive VR. In this paper, we analyze and explain the overall gameplay design principles and each pain metaphor element implemented in the game. We believe the design procedures and the way we implemented pain metaphors will inspire game design ideas in VR health game design and provide potentially useful references for other researchers and game designers.*

*Keywords:VR, Pain Distraction, Games for Health, Virtual Environments*

## Introduction

Immersive Virtual Reality (VR) has become more popular and widely accepted as a non-pharmacological analgesic in medical settings and health fields. In a number of research studies, VR has been considered successful as a method for distracting patients and reducing their perceived bodily pain, as well as managing emotional disorders associated with chronic pain, such as overcoming anxiety [8].

VR applications have been shown to help patients with acute pain from dental procedures [1], cancer-related treatment [16], and burn patient wound debridement [8]. Besides acute and cancer pain, there are also emerging studies that suggest chronic pain patients can benefit from VR applications as well [17]. Chronic pain patients require long-term pain reduction strategies, but they also suffer from shorter-term spikes in pain intensity, as well as sequelae, or other disorders that result from chronic pain such as anxiety. However, few virtual environments and VR games have been developed for or researched with chronic pain patients.

Chronic pain is a complex disorder because it involves neurobiological, psychological and social dimensions, and as such, no universal treatment exists [6]. Although pharmacological approaches are the most common treatment method, they cannot address all aspects of the condition. Moreover, analgesics such as opioids can have serious side effects, including dependency [12], and the misuse of opioids is a fast-growing problem in North America..

In this paper, we first discuss the game mechanics deployed while designing this virtual environment. Then we introduce *Mobius Floe* (MF), the immersive VR game we designed as a form of pain distraction. This game aims to build upon non-pharmacological analgesic research for acute pain, and to expand it for chronic pain patients by improving the quality and variability of the distractive gameplay, and by focusing on directing the players' attention. Tasks and pain metaphor components involving cognitive distraction and heightened cognitive load are discussed in game design section.

## Related Work

Numerous studies and experiments have been conducted on exposing pain patients to VR environments for clinical treatment [18]. Initial studies of VR technology for acute pain distraction primarily involved soldiers with burn-injuries. *SnowWorld,* an immersive VR that was developed for this purpose by Hoffman et. al. [11], is described as drawing patients' attention away from their pain experience and into the 3D environment. This virtual environment featured a "rail" path through a snowy landscape where patients could hurl snowballs at snowmen characters. This study demonstrated that patients who were undergoing burn debridement reported less pain when distracted by an immersive virtual environment (VE) coupled with a head-mounted display (HMD), and equipped with tracking devices that change the visual field in response to head movement.

VR distraction methods also have been shown to be superior to other forms of distraction. In a study of two adults undergoing painful dental procedures, Hoffman, Garcia-Palacios et al. [9] demonstrated that viewing an immersive virtual environment resulted in lower subjective pain ratings during painful dental procedures than watching a movie without VR technology. Hoffman also found that immersive VR distraction using *SpiderWorld* resulted in lower subjective pain ratings in two adolescents undergoing wound care for severe burns compared to trials in which they played *Mario Kart* or *Wave Race* on a Nintendo without the addition of any VR technology. Another study concluded that VR immersion had been very successful by "the amount of attention (it) drew away from (the) real world and allowing patients to tolerant painful dental procedures" [9].

Dahlquist et. al. [3] suggested that interactive distraction is significantly better than passive distraction, although both were effective. They argued that games not only stimulate visual and auditory sensations, but can also provoke tactile and kinesthetic sensations as the game is played, thus increasing attentional demand, which is consistent with capacity theories of attention. Moreover, they used a VR HMD for a distraction procedure. Most HMDs occlude or block sensory awareness of surrounding inputs. While occlusion might reduce sensory awareness of a player's surroundings, it may also focus players' attention on the VE and on their interaction in the VE. Moreover, the immersive aspect of VR might also elicit sensations such as proprioception. Additionally, this approach may have had a high level of patient acceptability.

However, the players of the VR environments tested by the above researches had very minor agency within the virtual worlds, few influences on the gaming environments and minor control over the whole experience. For example, the gameplay of *SnowWorld* is a simple shooting task, and the only interactivity between the virtual world and the player is the snowball. The simple actions are rather isolated and unlikely to keep the patients' mind busy for an extended period of time. There is also no perceivable consequence to inaction in that VE when clear reactions from the game world, in response to the player, are necessary to create a more engaging experience.

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Therefore, in order to cater and tailor the VR game to a wider range of pain patients, as well as to bring more engagement and flow to the players, we designed *Mobius Floe.*

## Design Approach

Virtual reality functions as a pain distraction tool through immersive visual impact, and the consequent high-level of immersion experienced. Pain patients experiencing immersive VR can become so deeply immersed in the virtual world that much less attention will be spent in processing bodily pain.

We demonstrated the fundamentals of designing *Mobius Floe,* a VR game, as well as how it functions from three aspects: cognitive attentional distraction as the basic pain management strategy, a strong sense of immersion and embodiment in the virtual world, and relaxation and anxiety control. We also illustrate the design theories, and explain how they function and why they work for pain distraction.

### *Cognitive Distraction as a Pain Management Strategy*

Attentional state is possibly the most commonly studied psychological variable that is thought to modify pain perception [19]. The influential gate control [15] and neuromatrix theories of pain [14] both state that attending to pain is one way of increasing the experience of pain. Therefore, diverting attention away from pain is a key to managing it. It is thought that individuals are less likely to notice pain when they are distracted by cognitively demanding tasks. In their review, Fernandez and Turk [5] found imagery methods to be the most effective forms of distraction and pain-acknowledging distraction techniques the least effective. Accordingly, the greater the attentional capacity a form of distraction demands, the more effective it is at reducing perceived pain. This is consistent with theories regarding attention as a limited pool of information processing resource. While the evidence for these theories are strong, it is also worth noting that mindfulness-based stress reduction (MBSR) has also been shown to be an effective way for patients to self-manage their pain [13]. This may initially appear to contradict the findings of Fernandez and Turk, since MBSR is a practice that requires patients to focus on their pain. However, the crucial difference is that MBSR has patients focus on their pain *in order to learn how to exert agency over it.* This is very different from merely acknowledging pain. Moreover, this is especially important regarding chronic pain, as people who suffer from this disorder frequently report a sense of hopelessness and a loss of control [7], and MBSR affords patients at least some degree of control over their experience of pain.

Given that an individuals' attentional capacity is considered finite, a distracting task that requires a great deal of the person's attentional resources should leave little attentional capacity available for processing painful stimuli. Moreover, multiple resource theories suggest that attentional resources within different sensory systems function relatively independently; an activity that involves one sensory modality may not necessarily deplete the attentional resources in another sensory modality. Thus, a highly engaging and interactive distraction activity that involves multiple sensory systems are likely to be more effective than a more passive form of distraction, or even a distractor that involves only one or two sensory systems.

*Mobius Floe* aims to learn from VR predecessors like *SnowWorld* and to improve upon them. By extending the software's ability and by implementing more engaging game components with pain metaphors, *Mobius Floe* could become more immersive and provide more cognitive distraction for pain management. It also incorporates theories and techniques from cognitive science. For example, we integrated n-back and attention switching tasks. These function together to increase cognitive load in the form of tasks that are presented to players throughout the length of the game, providing continuous action and constantly capturing and directing their attention. For example, Neuron Tree characters will attack the players when they're within proximity, while secondary tree characters that look like environmental trees will start moving, surprising the player when they're within proximity as well (Figure 3). This will require players to switch their attention between their tasks and the environment in order to look out for other potential harm. Further into the game, players are prompted to complete an n-back memory task where they have to remember the order of the objects lined up in front of them (Figure 5). As they continue further down the guided path, they are then presented with the opportunity to receive a bonus item when they complete a puzzle in the correct order. As we aim to provide pain distraction for as long as possible in one sitting, one of the methods we employed to fulfill this goal is through a procedurally-generated landscape. This ensures that the game does not end before the player has received as much of the pain distraction as they need. Since landscape tiles are constantly being randomly plotted in front of the current tile the player is on, players might find it harder to anticipate what is coming up next. This allows for a different experience each time patients play the game, which may therefore renew their interest in proceeding through the game.

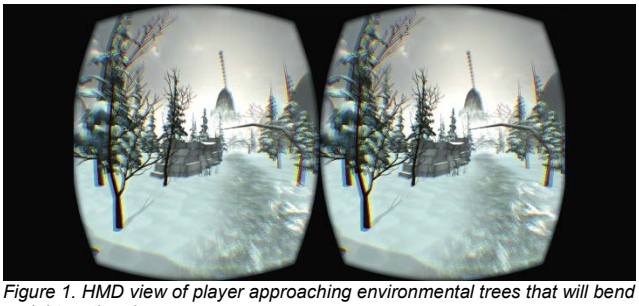

*Figure 1. HMD view of player approaching environmental trees that will bend upright as the player nears.*

### *Strong Sense of Immersion and Embodiment in Virtual Reality*

Virtual reality (VR) utilizes innovative technology and software to display virtual environments to users through a stereoscopic head-mounted display. Head tracking allows a user to interact with and actively view the VE in 360 degrees. Therefore, the images that users see are directly affected by the position of their head and its moment-by-moment movement. In addition, users can manipulate the virtual environment, usually through a mouse, keyboard or handheld devices. These advanced systems allow users to interact with the virtual environment on many levels, exploiting many of their senses, and encouraging them to become immersed in the world they are experiencing.

Immersion relates to how present the user feels in the VE and how "real" the environment seems. When immersion is strong, much of the user's attention is focused in the virtual environment, leaving little of it to notice other things such as pain.

*Mobius Floe* enables patients' attention to be drawn away from their embodied experience of pain and towards the virtual space and

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its current happenings. A patient is able to look around the VR game world using the Oculus Rift HMD, or with a mouse if preferred, as they are guided through the environment. Patients are presented with a world so captivating that it enables them to feel a sense of embodiment, as if they are inside or part of the virtual world itself. To better achieve this, we employed three types of digital immersion: sensory, challenge-based and imaginary [4].

In *Mobius Floe,* sensory immersion is achieved through realistic visual environments and ambient sounds to help draw players into the virtual space. HMDs and headphones also occlude much of the physical world, which may otherwise distract players in unwanted ways. Challenge-based and imaginary immersion take form as playful or threatening characters scattered throughout the environment interact with players to keep them on their toes and constantly focused on the game. Last but not least, a storyline ties all the elements in the game together, making them relevant and coherent. Players can also experience greater depths of immersion when they can identify themselves with a character or a role they're playing in the VR game world, enabling them to become more emotionally involved as described in *A Grounded Investigation of Game Immersion* [2].

## The Game Design

In this section, we analyze and explain the overall design of the VR gameplay as well as each pain metaphor we implemented in *Mobius Floe* in terms of how the game concepts relate to the pain distraction mechanism.

### *A Journey through the Snowy World*

Players are initially immersed in a virtual wintry setting where they glide through snowy paths and trails while experiencing action-packed encounters. The journey takes the player from a cozy cabin (Figure 2), out to a snowy landscape, and up a perilous mountain while constantly facing them with barriers and enemies that they have to contend with to get through.

*Figure 2. An initial orientation for new players is provided in the Tutorial Cabin.*

### *The Tutorial Cabin*

In the beginning of this journey, new players start inside a cabin that is located in a corner of the snowscape (Figure 2). Since many of our patients are elderly adults who rarely play video games, we implemented this cabin as an orienting tutorial, specifically for training purposes. In the cabin, the player learns about player controls and how to interact with the environment, and is presented with an introduction of the game. Such a tutorial-style preparation is necessary to help ease patients into the virtual environment as well as to allow them to adapt to the game interactions.

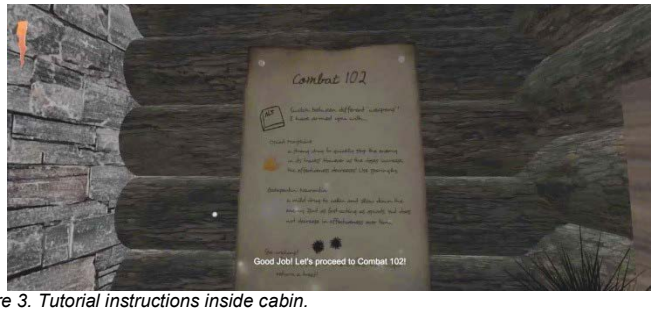


*Figure 3. Tutorial instructions inside cabin.*

### *The Neuron Trees*

After completing the training inside the cabin, the player then explores the outside environment on a pre-defined path or invisible "rail." As patients pass trees, they soon find themselves being approached by certain "trees" — monsters that appear to be half-neuron and half-tree (Figure 4). The Neuron Trees signify the dysfunctioning neurological systems in the human body that are part of what is causing the pain experience.

Neuron Trees have menacing expressions and require sedation for the player to successfully escape. They lumber toward or slowly "chase" the player and will damage the player's Health Points (HP) if they make contact. Neuron Trees also serve as a key mode of cognitive distraction as they coerce the player into taking defensive actions against them in a strategic and time-sensitive manner. They appear in multiple areas throughout the player's path in differing numbers, positioning, and even ambush methods.

*Figure 4. Neuron Trees. Because these dysfunctional, tree-like monsters blend into the landscape, players must continually look out for them throughout the game.*

### *Projectiles*

Players can choose from three types of projectiles: sea urchins they can toss to feed Otter characters, and morphine and gabapentin that they can fire at marauding Neuron Trees. For instance, patients are able to calm the Neuron Tree characters down by firing abstract analgesics at them with a mouse click. Each projectile has its own functionality, all of which are described for the player inside the tutorial cabin (Figure 2). Sea urchins are treats for sea Otter characters should the player choose to receive help from them. Overuse of drugs with the Neuron Trees, however, results in negative consequences: some manifest as detrimental behaviors by the Neuron Trees, while others affect the visual rendering of the virtual space in a negative way. For example, overuse of morphine slows the Neuron Trees down considerably, but they become more aggressive once the effect of morphine wears off.

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The depictions of drugs and their effects in *Mobius Floe* can represent pain patients' affective experience by translating the effects of each analgesic into gameplay, including the differing effects each drug has, as well as the consequences of overuse. Administering drugs to the Neuron Trees stimulates the working memory of the pain patients, and at the same time implies that the patient's sensation of bodily pain is being addressed by their active participation in the game.

### *The Health Points*

The Health Point (HP) mechanics associates the player with the gameplay experience and lets them know how well they are performing in the game. Players earn points and can also collect bonus "health packs" when they successfully complete certain tasks. Simultaneously, HP may act as a motivator to keep players focused on their tasks. The HP is visually depicted as a red icicle, as seen in multiple figures in the top left space of the screen (refer to Figure 5).

### *The Otters*

Sea Otters (Figure 5) are characters that also wander the game space and can interact with the player. The trickster-like and helpful Otters were implemented to represent help and concern from the players' family and friends, as well as encourage play. Unlike Neuron Trees, they are friendly entities in the game, and approach the player on sight. The patient can toss sea urchins to the Otters in much the same way they fire analgesics at the Neuron Trees. Otters that receive sea urchins will point or drop bonus items such as health packs.

*Figure 5. Otters greeting and offering instructions to players in* Mobius Floe.

## Discussion and Conclusion

*Mobius Floe* is an immersive VR game designed as a tool to help chronic and acute pain patients lower their pain and anxiety by providing an immersive form of pain distraction. The n-back tasks discussed in the previous section, sea otters and neuron trees will be in the proximity of the player at the same time, encouraging attentional switching and dual-task paradigms. Players must switch their attention between the Neuron Trees' location, the n-back task memorization, their Health Points and the Otters, fully engaging their cognitive load. For example, players may find themselves fending off Neuron Trees, trying to memorize the n-back task hint and trying to feed the otters simultaneously or in quick succession.

In future work, we plan to conduct focus groups comprised of patients who have acute and chronic pain. We will focus primarily on how patients evaluate the pain experience metaphors implemented in *Mobius Floe*. By situating *Mobius Floe* within health and serious game research, and by specifically focusing it on pain distraction, our novel approach, theoretical grounding and use of game design metaphors may provide more insights and inspirations for other researchers and game designers.

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## Author Biography

**Dr. Diane Gromala**, PhD, directs the Pain Studies Lab and the Chronic Pain Research Institute. Dr. Gromala is a Canada Research Chair and a Professor in the Simon Fraser University's School of Interactive Arts and Technology (SIAT). Her research works at the confluence of computer science, media art and design, and has focused on the cultural, visceral, and embodied implications of digital technologies, particularly in the realm of chronic pain.

**Xin Tong** received her MSc from SIAT and is pursuing her PhD degree at the Pain Studies Lab. Her research interests are designing technology for healthcare and patients, including Virtual Reality, digital games and wearables.

**Prof. Chris Shaw**, PhD is a Professor and Associate Director of the School of Interactive Arts and Technology (SIAT) at Simon Fraser University. - His current other areas of expertise are in the areas of bioinformatics, visual analytics and two-handed interfaces for 3D applications. Prof. Chris Shaw teaches visual analytics, interactive visualization, video game design and human-computer interaction.

**Ashfaq Amin** is a UX Designer and an MSc student under the supervision of Dr. Gromala. His research interest is in the user experience of everyday objects which have potential for mass use. Currently, he is investigating the potential uses of Cardboard VR as a means of pain distraction.

**Servet Ulaş** is a PhD student at Simon Fraser University. He received his MA from Sabanci University in Istanbul. His research interests are in the areas of interaction design, game design, physical computing and bodily interaction.

**Gillian Ramsay** is an undergraduate student in her 3rd year of a BSc in Interactive Systems with a minor in Computing. She is interested in immersive environments and using 3D games to educate, self-monitor and promote the healing of patients with chronic pain.